

An Introductory Review on Nanoparticles Based Treatment of Cancer

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ABSTRACT

Cancer is a malignant disease that is the leading cause of death globally. Different prevention and treatment techniques are used to combat such a disease with one of the highest prevalence rates. These include medicine, surgery, conventional chemotherapy, radiation therapy, and some targeted therapies. All these treatments and remedies have proved useful for the results and survival probabilities; however, they have some primary limitations. These limitations, such as multi-drug resistance and non-selective tissue toxicity in drug delivery, sometimes do more harm than healing. To reshape healthcare strategies for cancer, nanotherapeutics is one of the emerging techniques under high experimentation with the least toxic harm observed so far. Nanotherapeutics gives a brand-new frontier for cancer treatment. Nanotechnology has raised the bar by delivering the targeted drug with nano-carriers, effective tumor-targeting nanoparticles, nano-biosensors, and nanomedicines without failure. Advancements in nano-therapeutics have imparted a new horizon through multifaceted applications of nanoparticle usage in nanotechnology. There are also some challenges for modified and functionalized nanomaterials, such as making the correct formulations, enhancing localization, increasing rates of biodistribution, and biocompatibility. Furthermore, this enhanced imaging capacity for cancer diagnosis can be further translated to targeted therapies resulting from these material characteristics. This review summarizes the potential usage of nanoparticles by highlighting their role in targeted drug and gene delivery alongside their vital role in cancer treatment through nano-therapeutics.

Keywords: Cancer; Nanotherapeutics; Nanotechnology; Targeted drug delivery; Nanoparticles; Nano-materials; Cancer treatment; Pharmaceutical; Tumor; Gene therapy; Polymers.

1. Introduction

Cancer is a malignant disease in which the cell grows abnormally due to its uncontrolled division. It is one of the maladies with the highest prevalence rate globally. It is also one of the main causes of death in the world, despite the new technologies and treatments used. Cancer, as a disease, has been under treatment for so many years due to its high occurrence rate (Chandraprasad, Dey, & Swamy, 2022). Different techniques are used for its treatment as the research criteria expand to find the cure. Many medicines and several therapies are used, yet so many more are under experimentation for the treatment of cancer. These include the blend of chemotherapy, radiation therapy, and some targeted drug delivery therapies (Jin, Wang, & Bernards, 2023). Proteomics and genomics play an important role in uncovering how to treat cancer. Great progress has been made to develop new technologies and different therapeutic agents to treat cancer (Kwon et al., 2021). One of these significant technologies to treat cancer is nanotechnology.

Nanotechnology is a branch of biotechnology that deals with the study of performance and use of technology on a nano-scale. At the nano-scale, nanoparticles that are the size of 1nm to 1000nm are used. These nanoparticles are ultrafine, nano-sized particles with newfound optical, primary, and electronic-structural properties (R. Sharma, Sharma, & Kumar, 2022). Nanotechnology can provide an autoimmune alternative for the lives of cancer patients by improving their quality and expectancy (Sahu et al., 2021). Conventional chemotherapeutics and radiotherapy have failed to provide efficient cancer treatments, so nano-therapeutics play a pivotal role in enhancing cancer treatment (Bukhari, 2022). Nano-therapeutics are efficiently working as novel delivery systems for targeted drug delivery in cancer (L. Zhou et al., 2022).

The nanoparticles used in cancer treatment are seen to have antimicrobial activities. This approach is better than chemotherapy as the risk of reducing survival rate and severe side effects are well-known (Gao et al., 2022). Chemotherapy destroys healthy cells alongside the cancerous cells and can adversely affect the immune system, causing fatigue, infections, anemia, hair loss, and many more alarming conditions (Schirrmacher, 2019). Nanoparticles are colloidal particles, normally with a remedial factor enclosed in the molecule framework, adsorbed or formed through practical changes onto the surface, bringing about better educational stability and targeted viability (Mabrouk, Das, Salem, & Beherei, 2021). The layered comparability of nanoparticles to biomolecules, high surface volume proportion, and their ability for surface modifications have made their amazing assets in finding, imaging and treating cancer (Mokhosi, Mdlalose, Nhlapo, & Singh, 2022).

1.1. Introduction to Nano Particles Based Gene Therapy in Cancer

Gene therapy has generated a substantial amount of attention as an appealing treatment modality for many human gene-related diseases such as cancer, hemophilia, and hyperlipidemia (Sayed et al., 2022). Gene therapy has also been considered as a possible cure for conventional chemotherapy. Overall, gene delivery boils down to introducing the genes in diseased tissues or cells by modifying via endogenous genes – this could be aimed at either curing or stopping further progression of the associated disease (Arjmand et al., 2020). Gene delivery has been widely researched in different disciplines as a potential replacement for conventional treatment that often does not treat several diseases caused by genetic defects. It has become one of the most promising biomedical techniques close to its clinical applicability (Yahya & Alqadhi, 2021). However, without a proper vector, the uncovered genes cannot be introduced directly into the target cells. Thus, the main challenge to gene delivery is establishing the proper way of delivering therapeutic genes into target tissues (Sayed et al., 2022).

Nanoparticles have been introduced as a potential replacement for conventional gene delivery methods due to their well-controlled gene delivery efficiency and low-profile toxicity. Nanoparticles are excellent gene delivery mediums, characterized as particulate dispersions or solid particles that vary in size (Ebrahimi et al., 2023). Nanoparticles can travel via the circulatory systems and pass through several physiological barriers due to their small size and high surface area to volume ratio, which allows them to alter the functional group of the particle, hence further allowing the control of the particle's pharmacokinetics and bio-distribution (Xu et al., 2023). The biodegradable polymeric nanoparticles, especially those that are covered with hydrophilic polymers like polyethylene glycol (PEG), have been of great interest because of their potential to transport proteins, peptides, and genes as well as their lengthy plasma circulations half-lives (Gagliardi et al., 2021).

2. Gene Delivery Methods in Cancer Therapy

So far, virus vector systems, cationic polymers, and physical gene delivery techniques have been investigated. Gene delivery can be performed by many methods, including gene guns, electroporation, and viral vector gene transfer. In this article, some of these techniques have been compiled briefly.

2.1. Viral Vectors

Adenoviruses, retroviruses, and adeno-associated viruses have all been investigated as potential therapeutic gene delivery methods. In many circumstances, these viral vectors can efficiently spread genes by increasing cellular

absorption through intracellular pathways. On the other hand, broad-scale generation of viral vectors can be problematic, and repeated doses can frequently result in a severe inflammatory reaction. The external DNA integrating into the genome through viral vectors is also a major safety concern (Mahoney, Nassif, O'Brien, & Simpson, 2022).

2.2. Cationic Polymers

A significant number of cationic polymers have been discovered, investigated, and employed as non-viral gene carriers in recent years. Natural polymers like chitosan and dendrimers like polyamidoamine (PAM) and poly-L-lysine (PLL) are among them (Y. Zhou et al., 2020). Some polymers can be chemically altered to enhance their functionality, like improving transfection activity or lowering toxicity. As a result, a small number of polymers have several derivatives (Piotrowski-Daspi, Kauffman, Bracaglia, & Saltzman, 2020). In addition, cationic polymers can transfer amine groups at neutral pH, so positively charged polymers interact with negatively charged DNA, resulting in polymer/DNA complexes (polyplexes). Polyplexes are nanoscale transfection units that are smaller and more stable than lipoplexes. One of the most extensively used cationic polymers, polyethylenimine (PEI) is also one of the most successful polymeric gene delivery materials (Ooi, Wen, Zhu, Song, & Li, 2020). PEI comes in both branching and linear structures, and its size, molecular weight, and polymeric-DNA charge ratio all influence its gene delivery effectiveness and cytotoxicity (de Oliveira et al., 2021).

2.3. Electroporation

Electroporation involves an electric field to produce nanometer holes in the plasma membrane, allowing negatively charged particles to infiltrate. For the first time, in vivo, electroporation was used to transport medications into tumors in animals and human beings. This method was then tested to see if it could improve circular DNA delivery. In vivo, electroporation is nearly uniformly suitable to all tissues and organs studied, including muscle, liver, lung, skin, and various cancers. Furthermore, electroporation over conventional gene delivery technologies has various advantages, including safety, high effectiveness, and reliability. However, this approach is limited to in vivo solid tissues since electrodes must be put closer inside target organs. More basic research and technological advancement are needed to accelerate its clinical implementation (Nikyar & Bolhassani, 2022).

2.4. Gene Gun

The gene gun method, also known as Ballistic DNA injection or Gene-coated particle bombardment, has been utilized to transport genes into the skin, muscle, surgically exposed tissue, or tumor cells despite being originally designed primarily for plant transformation. Moreover, particle size, gas pressure, and dosage frequency all affect the effectiveness of the gene gun method. Although gene guns have been widely used for intramuscular, intratumor, and intradermal routes when compared to needle injection, there is some indication that they trigger the immunological responses at lower doses (D. Sharma, Arora, Singh, & Layek, 2021).

2.5. Nanoparticles

Nanocarriers or nanoparticles are novel gene transporters with a range of therapeutic and biological features involving the capacity to target specific disease areas, biocompatibility in the body, and sensitivity to

environmental stimuli. Nanoparticles are the most encouraging for clinical gene transfer therapy due to their configurable size, shape, surface, and organic features (Yetisgin, Cetinel, Zuvin, Kosar, & Kutlu, 2020).

3. Nanoparticles in Cancer Therapy

Nanoparticles have unique physical characteristics such as conductivity and optical properties, and their capacity for surface engineering has made it possible to use these particles as a tool in biology for cancer diagnosis and therapy. Nanotechnology has been widely researched and exploited for cancer treatments because NPs have a major role in targeted drug delivery systems. The nano-based drug delivery system has more advantages over conventional drug delivery, including greater stability, biocompatibility, increased permeability and retention effect, and precision targeting. The three major aspects that influence nano-drug delivery efficiency are specific size, shape, and surface characteristics (Bai et al., 2020).

Nanoparticles with a diameter of 10 – 100 nm are most commonly used for cancer therapy, as they deliver drugs efficiently and with increased permeability and retention. Smaller particles with less than 1-2 nm diameter can damage normal cells and get filtered by the kidney. However, larger particles with a diameter greater than 100 nm can be easily phagocytosed (Raj et al., 2021). Additionally, their surface characteristics influence the bioavailability and half-life of NPs. Usually, all NPs are made hydrophilic; this increases the duration of a drug in the body, also increasing the penetration and accumulation in the tumor (Rahman et al., 2022). Several nanotechnology-based products are used as drug delivery carriers in cancer therapy. They can be either organic nanoparticle, inorganic nanoparticles (Thakuria, Kataria, & Gupta, 2021). Liposome-based nanoparticles, polymer-based nanoparticles, viral nanoparticles, and dendrimers are among the organic nanoparticles. Polymeric nanoparticles are the most common of all. Among the inorganic nanoparticles are carbon fullerene, silica, magnetic, and quantum dots are most widely used in cancer therapy.

3.1. Types of Nanoparticles Used in Cancer Therapy

There are basically two types of nano particles classified as organic nanoparticles and inorganic nanoparticles. These types are further classified into subtypes based on their physical and chemical properties.

3.1.1. Organic Nanoparticles

(i) Liposomes

Liposome was the first nanoscale drug that was approved for pharmaceutical use, and it was discovered by D. Bangham in 1961 (Gosavi Pallavi, Somani Shravan, Rode Abhijit, & Jadhav Akshay). It is composed of an outer lipid layer, making excellent carriers of both hydrophilic and hydrophobic drugs. Liposomes can imitate biophysical features (e.g., movement and deformation) by changing the structure of the cell membrane's lipids, making it a very effective delivery drug (Andrade, Ramalho, Loureiro, & Pereira, 2021). In cancer therapy, liposomes are a useful source of in vivo administration of several anti-cancer drugs, particularly doxorubicin and paclitaxel, as well as other chemotherapeutic agents. The application of liposomes in breast and prostate cancer has been largely used (Yan, Leung, & To, 2020). Additionally, the liposome-based nano system has given us the option to combine drugs, which enhances the effect and also drug resistance. The approved liposome-based drugs for the treatment of metastatic breast cancer are Doxil®, Myocet®, and DaunoXome® (Layek et al., 2020).

(ii) Dendrimer-based Nanoparticles

Dendrimers are macromolecules with tree-like branches. Chemical and physical reactions are used to alter the surface of dendrimers. Drugs are attached in the form of a complex or a capsule. The first dendrimer nanoparticle system introduced to the pharmaceutical market is Vivagel®. It is an antiviral drug used locally to prevent the spread of human immunodeficiency and herpes virus. This substance stops the virus from attaching to the host body because of its dendrimer structure (Verma, Alam, & Mishra, 2015).

(iii) Polymeric Nanoparticles

Polymeric nanoparticles are the most widely used nanoparticles for the targeted delivery of anticancer cells because of their high stability and bulk production. The polymer nanoparticles usually used are of the biodegradable type. Polymeric nanoparticles contain vesicular (nano capsules) and matrix systems (nanosphere). In the vesicular system, the medicine is placed in a polymer cistern. In a polymer matrix, the medicine is spread on the polymer matrix (Taghipour-Sabzevar, Sharifi, & Moghaddam, 2019). Abraxane is the first polymer nano-sized drug released in 2005 by the pharmaceutical industry. It contains nanoparticles for the paclitaxel drug, which is bound to albumin and has been approved for the treatment of metastatic breast cancer (Wang, Porter, Konstantopoulos, Zhang, & Cui, 2017).

(iv) Viral Nanoparticles

Viral nanoparticles are promising tools in cancer therapy due to their special features. These organic nanoparticles can be designed to target cancer cells selectively. They can deliver treatments directly to tumor sites by encapsulating anti-cancer drugs or therapeutic genes within the viral particles, thus minimizing damage to healthy tissue. Viral nanoparticles also help boost immunity, making the body capable of fighting against cancer. They can be modified, which makes them usable in various types of cancer. Hopefully, research into viral nanoparticles could result in more effective and targeted cancer treatments (Gavas, Quazi, & Karpiński, 2021).

(v) Protein Based Nanoparticles

Trans-activating transcriptional activator proteins are a specific protein-based nanocarrier with a nuclear localization sequence. TAT proteins have the uncommon capacity to convey huge amounts of genetic information by destabilizing the plasma membranes, piercing plasma membranes, and defeating the lipid bilayer hurdle. The pharmaceutical nano-proteins have many polycationic regions attached to genetic material and produce stable complexes that protect the genes from the enzymatic activity of nucleases (Williams & Larsen, 2023).

Table 1. Organic nanoparticles: Role in cancer treatment, advantages, disadvantages and clinical research

Organic nanoparticles: Role in cancer treatment, advantages, disadvantages and clinical research				
Nanoparticle	Action in Cancer Treatment	Advantages	Disadvantages	Clinical Research
Liposome	These are Spherical vesicles delivering	Low toxicity, improved drug	Possible immune response, limited	Doxil (liposomal doxorubicin) is

	encapsulated drugs directly to the cancer site.	solubility, carries hydrophilic and hydrophobic drugs.	drug capacity, rapid clearance.	tested for ovarian cancer and Kaposi's sarcoma.
Dendrimer-based Nanoparticles	Highly branched polymers for precise control of drug delivery targeting specific cancer cells.	Capable of high drug loading, potential for targeted therapy, controlled drug release.	Complex synthesis, potential cytotoxicity, biodegradability issues.	Research in delivering methotrexate for targeting cancer cells.
Polymeric Nanoparticles	Biodegradable polymers for controlled drug delivery. Release drug over a period, concentrating therapy at the tumor.	Controlled/sustained release, biocompatibility, improved drug stability.	Unpredictable degradation rates, potential immune response.	PLA-PEG nanoparticles for delivering paclitaxel in breast cancer treatment.
Viral Nanoparticles	Modified non-replicating viruses to target cancer cells. Engineered to deliver therapeutic genes or oncolytic therapies.	High specificity for cancer cells, wide range of therapeutic agents, potential immune activation.	Safety concerns, immune response potential, production challenges.	Oncolytic viruses like T-VEC (Talimogene laherparepvec) for melanoma.
Protein Based Nanoparticles	Utilize proteins for drug delivery, targeting, and therapy activation in cancer treatment.	Enhanced targeting ability, biocompatibility, potential for controlled drug activation at tumor site.	Stability issues, potential immune reactions, complex fabrication.	Albumin-bound nanoparticles (e.g., Abraxane) for various cancers including breast and lung cancer.

3.1.2. Inorganic Nanoparticles

(i) Fullerenes

Fullerenes, also known as 'buckyballs,' are carbon-filled molecules. They have a hollow spherical shape. Due to their unique structure and physical, chemical, and electrical properties, they are considered the most efficient nanomaterials for delivering small therapeutic anticancer drugs. Their stable nature makes them effective for delivery against tumors. Moreover, fullerenes can also absorb visible light and release reactive oxygen species in

the presence of light, and This property makes them important for photodynamic therapy in cancer (Gaur et al., 2021).

(ii) Quantum Dots

Quantum dots are nanomaterials that are semi-conducting. They have brilliant fluorescence, a wide absorption spectrum, narrow emission bands, broad UV excitations, and good photostability. Quantum dots in conjugation with antibodies for prostate-specific membrane antigens were used to detect and target prostate cancer cells (Bock et al., 2021).

(iii) Magnetic Nanoparticles

Magnetic nanoparticles (MNPs) are a type of NP made from pure metals (Fe, Co, Ni, and some rare earth metals) or a combination of metals and polymers. The magnetic nanoparticle drug delivery principle is based on the principle developed by Widder and others late in the 1970s for magnetically targeted drug delivery (Seal, Saikia, & Borah, 2021). Superparamagnetic iron oxide nanoparticles coupled with luteinizing hormone-releasing hormones could be utilized to target and image breast cancer cells. Magnetic nanoparticles are coated with organic particles and show high efficacy in chemotherapy for treating cancer (Halder et al., 2022).

(iv) Gold Nanoparticles

Gold nanoparticles are the most widely studied inorganic nanoparticles, consisting of an inert and non-toxic gold core. Gold nanoparticles have been shown to increase drug accumulation and overcome tumor resistance. Gold nanoparticles absorb and scatter electromagnetic radiations; this property makes them useful in photothermal therapy. Gold nanoparticles can also be used for Radiofrequency ablation, one of the least invasive cancer treatments. In conjugation with other chemicals, spherical gold nanoparticles are used as drug carriers (Abadeer & Murphy, 2021).

(v) Mesoporous Silica nanoparticles

Mesoporous silica nanoparticle is a type of silica nanoparticle used for drug delivery. Due to their large internal pore volume, they can encase many anti-cancer drugs. Mesoporous silica nanoparticles are one of the finest vehicles for drug delivery because of their improved pharmacokinetics and high efficiency (Frickenstein et al., 2021). Furthermore, porous silicon NPs have shown considerable promise in immunotherapy, as their immunoadjuvant features include antigen cross-presentation, lymphocyte polarization, and interferon- (IFN- γ) production (Feng et al., 2019).

Table 2. Inorganic nanoparticles: Role in cancer treatment, advantages, disadvantages and clinical research

Inorganic nanoparticles: Role in cancer treatment, advantages, disadvantages and clinical research				
Nanoparticle	Action in Cancer Treatment	Advantages	Disadvantages	Clinical Research
Fullerenes	Unique carbon structures for drug	High drug loading capacity, versatile	Potential toxicity, environmental	Research in photodynamic

	delivery and photosensitizing agents. Can generate reactive oxygen species for therapy.	functionalization, photodynamic therapy applications.	concerns, stability issues.	therapy and targeted drug delivery systems.
Quantum Dots	Semiconductor nanoparticles used for imaging and targeted drug delivery. Can be used for real-time tracking of cancer cells.	Bright and stable fluorescence, size-tunable optical properties, multiplexed imaging capabilities.	Toxicity concerns, long-term stability, potential bioaccumulation.	Used in imaging for tracking tumor progression and drug delivery.
Magnetic Nanoparticles	Utilized for hyperthermia treatment and magnetic targeting. Can be heated remotely to target tumor cells.	Targeted drug delivery, controlled heating for tumor destruction, minimal invasiveness.	Biocompatibility issues, potential for aggregation, heat control.	Hyperthermia therapy in brain and breast cancers, magnetic targeting in chemotherapy.
Gold Nanoparticles	Used in drug delivery, and as contrast agents in imaging. Can absorb light and convert it to heat.	Efficient light absorption, easy surface modification, potential for targeted therapy.	Toxicity at high doses, potential accumulation in organs.	Photothermal therapy in various cancers, targeted drug delivery, and as contrast agents in imaging techniques.
Mesoporous Silica Nanoparticles	Porous structure allows for high drug loading and controlled release. Can be functionalized for targeted delivery.	High surface area for drug loading, biocompatibility, controlled drug release.	Instability in biological fluids, release control challenges.	Drug delivery systems for chemotherapy, targeted therapy applications, and in controlled drug release studies

4. Target Specific Nanoparticles for Cancer Treatment

Nanoparticles are necessary for the development of nanotherapeutics in oncology. The major obstacle in tumor treatment is poor penetration of the drugs into the tumor and targeting the tumor cells. Tumor cells carry certain

molecular markers that are not expressed or expressed at lower levels in the body's normal cells. These molecular markers are sites for docking the nanoparticles to the tumor cells. Understanding these differentially expressed molecules helps in nanoparticle-targeted drug delivery and tumor targeting. This targeted action of nanoparticles has the major advantages of low systematic exposure and higher local concentration at the tumor site. The use of antibodies conjugated to certain radioisotopes has long been practiced to treat leukemia, but the difficulty in drug delivery was the major issue (Gavas et al., 2021).

4.1. Methods for targeting of nanoparticles to tumors

An emerging nanotherapeutic class directed to neoplastic cells promises exciting opportunities for targeted drug delivery. This would make the use of nanotherapeutics advantageous over the conventional methods for cancer treatment. Targeting nanoparticles can be achieved in two ways: active targeting and passive targeting.

4.1.1. Active targeting of nanoparticles

In active targeting of nanoparticles, the nanoparticles, through ligand-receptor interactions, would recognize and bind to the tumor cells. The nanoparticles are internalized by the tumor cells before the drug release; therefore, there is less off-target drug release. An important method of active targeting is that of transferrin with gold nanoparticles. Notably, active targeting limits the side effects as it delivers to the location of interest, avoiding the healthy cells. After entering the tumor microenvironment, the treatment efficiency can also be increased by active targeting, achieved using ligands (Biffi, Voltan, Bortot, Zauli, & Secchiero, 2019).

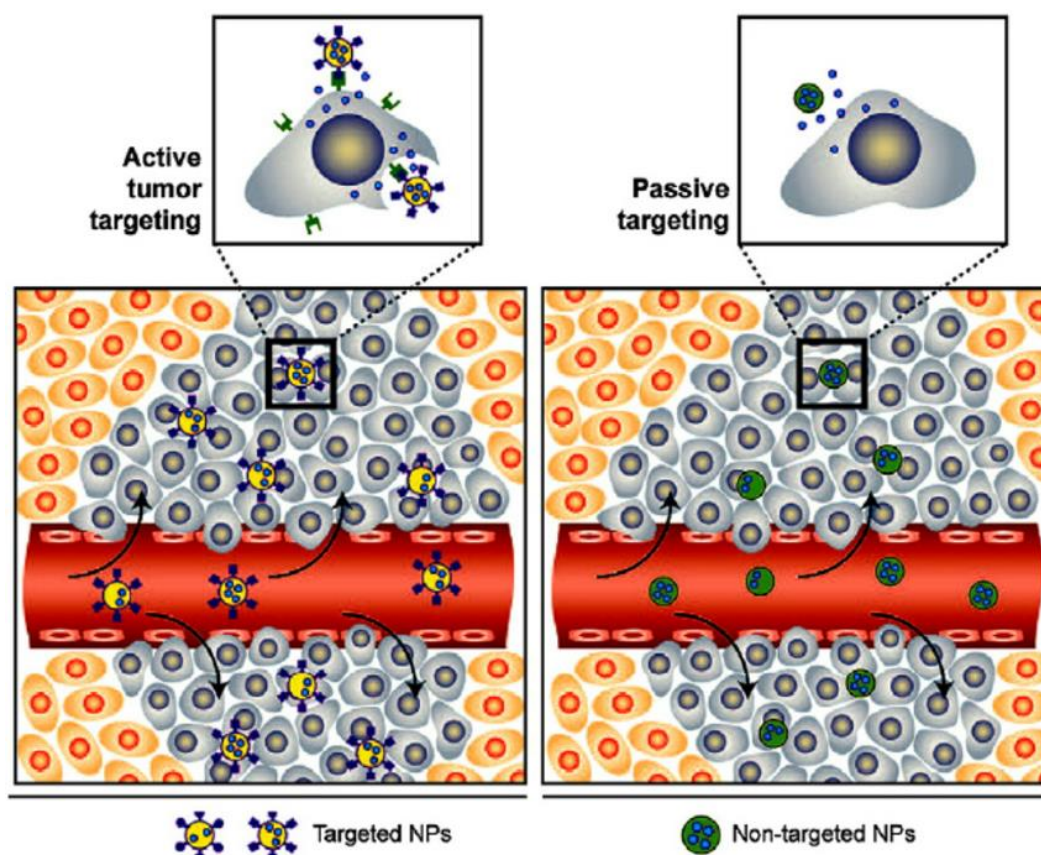


Figure 1. Active targeting vs Passive targeting of nanoparticles: Passive vs active targeting. (Right) By escaping from the vasculature, nanoparticles tended to infiltrate inflamed sites by means of their biophysiochemical

properties. (Left) Once nanoparticles have entered the target tissue, attaching targeting ligands (e.g., proteins) onto the nanoparticle surface can lead to active targeting of nanoparticles to receptors there and accomplished enhanced cell uptake and accumulation through receptor-mediated endocytosis (This image is taken from reference (Mahmoudi, Sant, Wang, Laurent, & Sen, 2011))

4.1.2. Passive targeting of nanoparticles

In this method, the nanoparticles accumulate in the tumor microenvironment. Passive targeting facilitates nanoparticle localization in the tumor microenvironment but does not facilitate nanoparticle uptake by the tumor cells. This type of targeting depends upon the tumor biology and the nanocarrier characteristics (i.e., circulation time and size) (Sebak, El-Shenawy, El-Safy, & El-Shazly, 2021). Since its discovery, many efforts have been made to understand the phenomenon of EPR (Enhanced Permeability and Retention effect). Nanotherapeutics exploit this EPR effect to target solid tumors. The modulation of EPR could increase the nanocarrier accumulation. Common chemical enhancers for EPR include prostaglandins, nitric oxide, and other cytokines (Subhan, Parveen, Filipczak, Yalamarty, & Torchilin, 2023).

5. Efficacy of tumor targeting methods

It has been proved that the targeting strategy does not matter; being therapeutically relevant is the most important factor determining tumor treatment efficacy. Various factors determine the cellular internalization of nanoparticles, including shape, size, and surface chemistry. However, the intracellular trafficking of nanoparticles and targeting mechanism remain poorly understood.

5.1. Aptamer Based Targeting

These are single-stranded DNA or RNA oligonucleotides, short in length and folded into two- or three-dimensional structures. This increases their ability to bind to specific targets. Their targeting specificity and high sensitivity make them a good alternative to antibodies. As they can be chemically synthesized, they are readily available rather than antibodies, which need biological systems, and thus, their production can be scaled up according to need. Moreover, in vitro production also provides a broad spectrum of target selection. They have a longer shelf life and lack immunogenicity, resulting in better biodistribution (Khan et al., 2022).

5.2. Antibody Based Targeting

Antibodies have high binding affinity and selectivity, making them appropriate for nano-vehicle use. In 1975, the first monoclonal antibody, mAb, was developed to bind to the tumor antigen. The FDA approves many mAb therapies while hundreds are still under clinical trial. The epidermal growth factor receptor (EGFR) and human epidermal growth factor receptor 2 (HER2) have been studied extensively (Nagayama, Ellisen, Chabner, & Bardia, 2017).

5.3. Transferring based targeting

A serum glycoprotein transfers iron by binding to transferrin receptors on the cell surface. Many liposomal nanocarriers are used to deliver doxorubicin (a chemotherapeutic drug) using transferrin. The transferrin-conjugated liposomes can target transferrin receptors expressing neoplastic cells (Mojarad-Jabali et al., 2022).

Transferrin-based gold nanoparticles show higher cellular uptake, proving that the efficiency of transferrin uptake can be improved by employing better nanocarrier cargos (Akhter et al., 2021).

6. Conclusion

The addition of nanotechnology in cancer treatment has brought about numerous advances and is proving to develop an important aspect of the healthcare system. Many medicines, surgery techniques, and therapies have been under use for cancer treatment. The three layers in the nanoparticle complex structure have proven to be a miracle for cancer therapies. Nano-therapeutics and nano-medicines, among all the treatment methods, have shown better results in cancer treatment. As far as medicines are concerned, nano-medicines have modulated drug release rates by changing the pharmacokinetics of the drugs. In gene therapy, nanoparticles such as nano-carriers have ended the concerns regarding the risky use of viral vectors, cationic polymers, electroporation, and gene gun techniques. Regarding targeted drug delivery treatment, nanoparticles play a role in targeted drug delivery by active and passive targeting. The potential risks of conventional chemotherapy and radiation therapy use are eliminated successfully by using nano-therapeutics that minimally damage the healthy cells, maintaining the normal working of the immune system.

7. Challenges and Future Directions

Nanotechnology is an evolving field with huge potential, especially in cancer treatments and other fields where its applications are new and on the rise. Treating cancer using nanostructures has become the focus of interest and has led to remarkable progress; however, a lot still needs improvement. These include the development of drugs targeted at molecular groups within cancerous areas. Such drugs are especially pertinent for cancers with unique gene and protein profiles. Physical and chemical changes and surface modifications of nanomaterials can improve their drug-loading efficiency. These strategies, however, have challenges, such as the instability of nanomaterials, the rise in multi-drug resistance, and the diminished accumulation rate for cancer cells. An innovative solution is using decorated nanomedicines to target cancer-specific molecular markers. The right choice of nanomaterial can deal with the problems associated with drug instability and is effective against multidrug-resistant tumors.

The precise design of nanomaterial-based drug carriers is essential. These carriers should support treatment with standard chemotherapy and other treatments like thermotherapy, photodynamic therapy, and radiation. While metal-based nanoparticles have considerable advantages, their potential toxicity is a serious issue that must be considered. Moreover, multidrug-loaded nanocarriers could potentially address issues relating to drug resistance, as the non-drug functionality of proteins is involved in different types of cancer. Hence, the approach to using drug carriers in nanoparticles and therapies needs further study at the preclinical and clinical levels. Now, there are some challenges for modified and functionalized nanomaterials, such as making the correct formulations, enhancing localization, increasing rates of biodistribution, and biocompatibility.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

All authors contributed equally in this review article.

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